Army Research Laboratory

Galvanic Skin Response as a Measure of Soldier Stress

by Chuck H. Perala and Bruce S. Sterling

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Human Research & Engineering Directorate, ARL

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14. ABSTRACT

This report discusses three methods of measuring Soldier stress: survey, salivary amylase, and galvanic skin response (GSR). Examples of recent studies using the survey and GSR methods are given and a discussion is provided outlining the advantages and disadvantages of each. A plan is suggested to develop a study that compares data taken from each of the three methods with the ultimate goal of determining if the GSR method is a suitable "middle ground" between the survey method, which is subjective and somewhat intrusive, and the salivary amylase method, which is very time consuming, costly, and intrusive.

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Contents

List of Figures

List of Tables

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1. Introduction

In the ever-increasing realm of "high-tech" Soldier systems, one factor remains fairly constant: the human factor. The use of multiple high-tech and increasingly complex systems is intended to add capabilities to Soldiers and in many cases to reduce stress and workload. However, these systems may well add increased levels of stress and workload onto Soldiers who are already at heightened levels of each because of the particular environments in which these systems are employed. As just one example, Dixon and Wickens (2006) found that diagnostic automation to assist unmanned aerial vehicle operators, when operated at less than 80% accuracy, resulted in more workload compared to no automation at all. In order to gauge what levels of stress and workload are being impinged upon these Soldiers, researchers and materiel developers have used a small number of tools at their disposal. The two primary tools used are self-report surveys and salivary amylase. Surveys are quick and cheap but subjective, while salivary amylase tests are objective but time consuming, intrusive, and expensive. As requirements increase to incorporate larger numbers of high-tech and more complex systems with Soldier-in-the-loop (SIL) systems, researchers will need a method to gather stress data in an accurate, timely, and less intrusive manner.

This report discusses the use of a third method to measure Soldier stress: galvanic skin response (GSR). The first step of this evolutionary process compared the survey method with the GSR method in an attempt to determine if GSR data are similar to survey stress data in terms of statistics and trends. The theory is that if these data are similar in the same experimental circumstances, this would provide impetus to pursue further research among all three methods: survey, GSR, and salivary amylase.

The ultimate goal of this research (this phase and ensuing research) is to determine if the GSR method is a suitable "middle ground" between the survey method, which is subjective and somewhat intrusive, and the salivary amylase method, which is very time consuming, costly, and intrusive. GSR has the potential to provide researchers with a tool for objectively measuring Soldier stress that is quick, effective, and unobtrusive during research, training, and operational conditions. Discussion includes results of the survey-GSR comparison and recommendations for ensuing research to examine the differences among all three methods.

2. Stress Measurement Methods

2.1 Survey Method

The primary tool used in the field has been validated stress surveys or questionnaires. Surveys provide a standardized method of soliciting how stressful a Soldier feels in a given circumstance or

situation and are a fairly easy and "low-tech" means to gather data. The primary disadvantage of surveys is that they are a subjective assessment of stress. This means the data are subject to the perceptual and cognitive biases inherent in all of us. The method for controlling (but not eliminating) such bias is to take a large sample of repeated measures of stress during a given experiment or event.

The stress survey used in this study was a simple pen-and-paper questionnaire, using a Likert-type scale measuring both physical and mental stress (appendix A). This survey was developed and has been used extensively by the U.S. Army Research Laboratory's (ARL's) Human Research and Engineering Directorate in field and laboratory environments (Keryl & Bialek, 1958; Perala, 2005; Sterling & Jacobson, 2006; Perala, Sterling, Scheiner, & Butler, 2007). Although quick and relatively easy to administer, the survey requires that after an experimental trial, participants must recall events and aspects of the trial and then rate (on a scale of 1 to 10) their perceived levels of stress in relation to those events and aspects of the trial. This is conducted at the end of every trial, and the experimenter collates the data collected from all participants for use in later statistical analyses.

2.2 Continuous Monitoring Method

One proposed method to collect continuous and objective data in a non-intrusive manner is by the use of GSR. Also known as *electrodermal response*, *psychogalvanic reflex*, or *skin conductance response*, GSR is a method of capturing the autonomic nerve response as a parameter of the sweat gland function (i.e., measuring the electrical resistance of the skin). As stress levels increase, changes in the electrical resistance of the skin are detected by GSR sensors. This method of nerve response detection is very similar to that used in modern polygraph tests.

GSR has long been considered a measure of physiological and mental stress (Fenz & Epstein, 1967). Although there are no absolute levels of GSR indicative of high workload or stress, GSR is a good relative indicator of stress. That is, higher GSR levels recorded during certain tasks suggest higher levels of stress. One caveat to GSR is that although there is a relationship between sympathetic activity and emotional arousal, determining the specific emotion being elicited is difficult. For example, fear, anger, startle response, orienting response and sexual feelings are all among the emotions that may produce similar GSR responses. However, controlling for these extraneous emotions may assist in parsing output into meaningful results. A more objective way to determine whether GSR is measuring stress (versus some other emotion) is to compare GSR data with other, known stress data. For example, comparing GSR data with survey stress data and salivary amylase stress data may provide sufficient evidence that GSR data captured during the same experimental conditions is actually measuring stress.

2.2.1 Bio-instrumentation Armband

The particular method used to collect GSR data for this report was via a small, lightweight, unobtrusive body monitor, called the SenseWear[1] Pro2 armband by BodyMedia, Inc. (Comparable products are available which measure similar autonomic functions.) The armband is worn on the back of the upper arm, which enables continuous physiological data collection outside a laboratory environment (see figure 1). Using metallic sensors close to the skin (see figure 2), the armband (as it is referred to throughout the text) collects biorhythmic data in real time, with a configurable sample rate, and gathers raw physiological data such as movement, heat flow, skin temperature, ambient temperature, and galvanic skin response. The armband may be worn for as many as 14 days continuously with the same internal battery and can store as many as 14 days (depending on the sample rate) of continuous physiological data. A data time stamp feature allowed the researcher to mark specific events in the data to facilitate later data analysis. The device is designed to provide auditory and tactile feedback during certain events; however, this feature was altered (through firmware modification) for this research, so this feedback did not interfere with the experimentation. Armband specifics are shown in appendix B.

Figure 1. BodyMedia SenseWear Pro2 armband worn by test participant.

[1]SenseWear and BodyMedia are registered trademarks of BodyMedia, Inc.

Figure 2. Metallic sensors on the underside of the armband.

2.3 Salivary Amylase

Another method to gather stress data, and one that is not subject to human bias, is the salivary amylase test. This is a very objective test that measures the amount of amylase found in human saliva. Amylase is an enzyme used to hydrolyze or break down starch molecules in the body. The levels of amylase in the body have been used as an effective measure of stress, including social stress such as performance in front of an audience (Nater, La Marca, Florin, Moses, Langhans, Koller, & Ehlert, 2006; Rohleder, Wolf, Maldonado, & Kirschbaum, 2006; Gordis, Granger, Susman, & Trickett, 2006; Nater, Rohleder, Gaab, Berger, Jud, Kirschbaum, & Ehlert, 2005; Rohleder, Natar, Wolf, Ehlert, & Kirschbaum, 2004), testing (Yamaguchi, Kanemori, Kanemaru, Takai, Mizuno, & Yoshida, 2004), competition (Kivlighan & Granger, 2006), and physical stress (Wetherell, Crown, Lightman, Miles, Kaye, & Vedhara, 2006; Chatterton, Vogel-song, Lu, Ellman, & Hudgens, 1996). Although objective, accurate, and repeatable, this method is time consuming, intrusive (experimentally as well as human intrusive), and costly and requires specialized laboratory equipment to analyze the saliva samples.

3. Experiments Using Both Survey and GSR Methods

The first step in this evolutionary process of stress measurement comparison was to collect actual GSR data in the field via the armbands. This was accomplished to good effect and is discussed in the section 3.1. The second step was to collect GSR data along with survey data during the same experimental conditions (sections 3.2 and 3.3). The third step was to collect data using all three methods (survey, GSR, and salivary amylase).

3.1 Head-Tracked Sensor Suite Evaluation

3.1.1 Introduction

The head-tracked sensor suite (HTSS) is a complement of optical, tracking, and display systems designed to provide vehicle commanders with the ability to visually scan a 360- by 90-degree hemisphere surrounding their vehicle in a closed hatch environment. The system also enables the vehicle commander to see beyond the immediate area for target and terrain detection, recognition, and identification in daytime and nighttime conditions, through the use of electronic imagery created by the fusion of forward-looking infrared and image intensification technology (see appendix C).

The objective of this study was to acquire preliminary user performance data and subjective user evaluations and to gain insights from the early prototype HTSS system for use in the development of the HTSS, version 2. Specifically, data were collected to determine the practicability of using the HTSS as a means to increase situation awareness (SA), reduce workload and stress, and enhance the vehicle commander's ability to detect, recognize, and identify (DRI) targets and terrain while moving in daytime and nighttime conditions.

3.1.2 Method

The original intent was to evaluate the HTSS with an M1A2 Abrams tank as the test vehicle platform; however, maintenance problems with the tank procured for this purpose precluded that intent. The alternate platform for this evaluation, an M1043 truck, was used in lieu of the M1A2 tank. The M1043 truck is an M998 high-mobility multipurpose wheeled vehicle (HMMWV) in the armament carrier (without winch) configuration. For this reason, certain aspects of the HTSS were unable to be evaluated during the study. Efforts were instead focused on the use of the system in target DRI. Participants, who were experienced armor crewmen, moved through a military operations on urbanized terrain (MOUT) and movement route to conduct various reconnaissance and surveillance tasks.

Target detection, recognition, and identification were defined as follows. Detection was defined as the point at which participants perceived an object on the screen that stood out from the environment. Detection was usually denoted by the participant stating something to the effect, "I see something at the tree line." Recognition was defined as the point at which participants were able to determine what the object was in general terms. For example, recognition occurred when participants were able to determine that an object was a wheeled vehicle as opposed to a shed, for example. Identification was defined as the point at which participants were able to correctly identify an object. That is, identification occurred when participants were able to determine that the object was, for instance, a "deuce and a half" instead of a 5-ton truck.

3.1.3 Results

Figure 3 shows the comparison of GSR values for MOUT and movement environments across each condition. Results indicate that GSR levels overall were less during the movement trials than during the MOUT trials. This may suggest that the shorter route, more confined space, and unpredictable nature of the targets in the MOUT environment were more stressful to the participants (using both the HTSS and night vision goggles [NVGs]) than the longer, less eventful scenario experienced in the movement environment. This seems to make sense and shows that the GSR values are representative of the events being measured. In both MOUT and movement environments, GSR levels were highest when the HTSS was used, except for the night-HTSS condition. This could be caused by the unfamiliarity with the HTSS system in a very familiar environment (target DRI, sector scanning, etc.). A larger sample size and more trials may yield lower GSR levels while increasing statistical power.

GSR levels in all conditions were lower than the baseline GSR levels. This may suggest that baseline levels were derived when anticipation levels were highest (before the event started), and levels dropped after participants settled into the job of performing specific tasks during each trial.

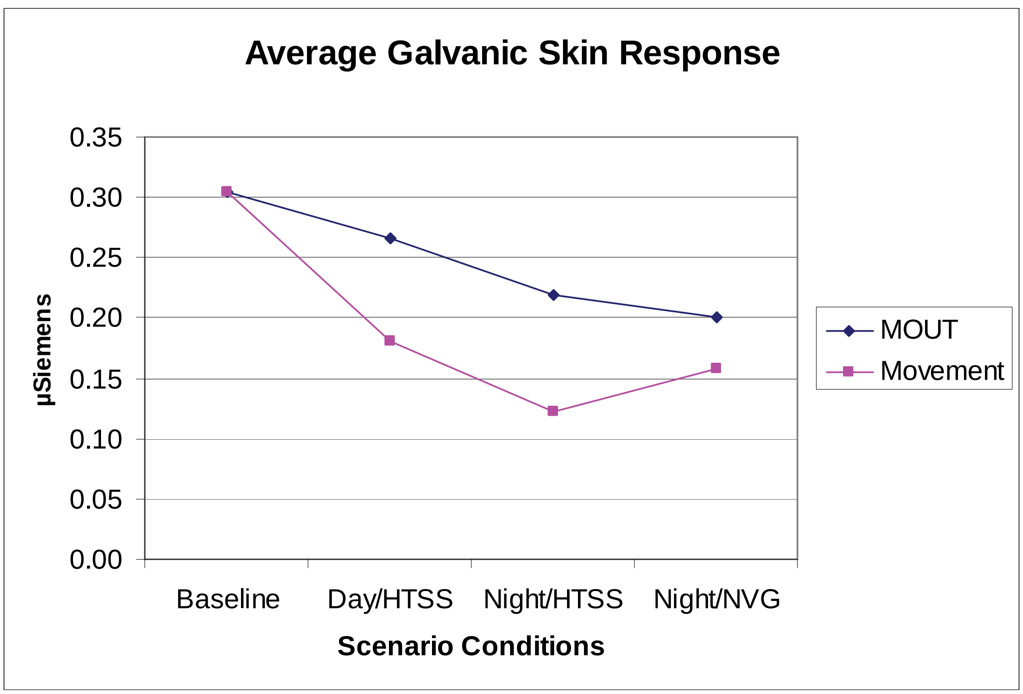

Figure 3. Galvanic skin response by scenario.

3.2 Aided Target Recognition Experiment

3.2.1 Introduction

Future scouts will have many simultaneous tasks with which to contend. They will be required to maintain overall SA using a common operational picture; receive instructions from and provide

information to higher headquarters; plan and adjust routes for manned and unmanned vehicles; monitor sensor locations; receive information from multiple sensors, synthesize that information, and provide actionable data to those who need it; and maintain local SA.

Because the scout must perform several ongoing tasks, sufficient time will not be available to simply focus on continuing sensor imagery. Furthermore, the battle space of the scout may be complex, with many objects that could be taken for targets. Thus effective aided target recognition (AiTR) technology is critical to reducing scout workload and enabling scouts to perform their jobs more effectively.

Several studies have demonstrated that AiTR improves target identification. McDowell (1992) showed that performance with AiTR was better than unaided performance when AiTR was 40% and 80% reliable. Similarly, Entin, Entin, and MacMillan (1994) demonstrated that AiTR at 80% accuracy increased hits in target recognition over unaided target recognition without increasing false alarm rates. Kibbe and Weisgerber (1991) showed that AiTR of 70% and 90% accuracy improved target recognition over unaided performance, but AiTR of 50% accuracy did not.

The AiTR technology considered in this study was not simply the sensor and the algorithms used but the entire Soldier-system interface. This included controls such as a mouse, joystick, and buttons. This also included displays that provided the Soldier with software menus, streaming imagery, digital maps, representations of targets on the terrain, and other features.

3.2.2 Method

Participants were seven experienced scouts (rank of Sergeant E5 or Major 04). The participants were recruited and trained in the use of the interface by subject matter experts working with the Night Vision and Electronic Sensors Directorate (NVESD) of ARL on this project. Since the interface involved only a few controls and functions, roughly 1 hour of training before the experiment was sufficient for test participants to be able to operate the system.

The interface consisted of two computer screens, a joystick control unit, a mouse, and a keyboard, in the rear of a HMMWV. The computer screen to the right of the scout provided a digital map of the battlefield and was referred to as the situation awareness screen or "SA screen" (see appendix D). The AiTR provided Soldiers with the ability to populate the SA screen with "lased[2]" targets. The computer screen directly in front of the scout, referred to as the crew station screen, provided all sensor feed imagery and was split into different sections; the top half could show a live view of a specific part of the terrain chosen by the scout when in stare mode or a selected static view from the gimbal scan mode, which was updated every 6 seconds. Symbols (color-coded brackets) for targets detected in the entire area selected for surveillance were displayed in three locations: a) within the image chips described next, b) in the top half of the screen where live and static imagery was displayed, and c) in the panoramic view that was displayed at the bottom of the screen.

[2]Lase means "to emit coherent light at".

When AiTR was activated, as many as ten small pictures of potential targets (called chips) were displayed from left to right in reference to their locations in the top and bottom screens just described. Algorithms assigned a confidence to target reports coming from AiTR boxes. The confidence comes from how target-like the detection is, based on measured features. The user could manually set a threshold of confidence for target detection. If the user sets a high threshold, few detections will be made and the likelihood of the detections being actual targets will be high. Conversely, if the user sets a low threshold, more detections will be made, but the chances of a detection being an actual target will be lower. When more than ten targets that meet the set threshold have been detected, the first detections drop off the crew station screen. Within the AiTR mode, stationary target indication (STI) or moving target indication (MTI) could be selected. The STI mode elicited a higher rate of false positives (e.g., hot spots caused by roofs on buildings). The MTI mode was much more reliable and had a false alarm rate of one to two orders of magnitude below STI but missed stationary targets. A scout could choose to use AiTR on a selected portion of an area so that, for example, a highway that contained much civilian traffic could be ignored.

The joystick unit controlled the movement and zoom function of the sensor in manual mode. Buttons on the joystick were also available on the screen and manipulated via the mouse. These buttons controlled sensor gain (contrast), level (brightness), and polarity (white hot versus black hot), pan, focus, wide and narrow field of views, two electronic zooms, and manual control of the sensor. Appendix D provides illustrations of the crew station and the joystick control.

The demonstration itself was organized, conducted, and controlled by NVESD. ARL researcher responsibility was the collection of data, as described in this report. The study involved five scenarios, including but not limited to watching for suspicious activity along a highway, watching for suspicious activity around an airport (reflects MOUT), observing activity at an Army installation gate (reflects a check point), observing activity along a "border" (reflects border patrol military operations), and observing open terrain. The scenarios occurred during day and night. Soldiers could choose whether to use AiTR during the scenarios. In a field test, however, it was not possible to counter balance the use of AiTR, scenario, and time of day for all scenarios. An example of the pseudo counterbalanced order is given in table 1.

Table 1. Counterbalanced scensrios and daylight conditions.

Day	Night	Day	Night	Day	Night
Highway	Airport	Check Point	Border	Open Terrain	Other
Airport	Check Point	Border	Open Terrain	Other	Highway
Check Point	Border	Open Terrain	Other	Highway	Airport
Border	Open Terrain	Other	Highway	Airport	Checkpoint
Open Terrain	Other	Highway	Airport	Check Point	Border
Other	Highway	Airport	Check Point	Border	Open Terrain

Data on workload and stress were collected multiple times during each scenario (day, night, AiTR activated, AiTR de-activated).

3.2.3 Results

All graphs showing combined GSR and survey stress data use two separate scales. GSR data are measured in micro-Seimens, and survey data are measured on a subjective rating scale from 1 to 10, with 1 being low stress and 10 being high stress. Generally, stress was low (subjective ratings) to moderate (GSR). Subjective survey stress was highest for the airport scenario, perhaps because of the complexity of the environment in terms of activity and distance to be covered (figure 4). Stress (both survey and GSR) were somewhat higher at night (figure 5), which suggests that identifying targets from only a thermal signature and the inability to use terrain features available during daylight may be more challenging. However, night scenarios may be less stressful for scouts who have more experience using thermal imagery at night. The GSR and survey measures of stress by use of AiTR are presented in figures 6 and 7, respectively. Stress measures suggest that intermittent use of AiTR results in greater stress than not using AiTR, perhaps because of the necessity of constantly switching modes and the effects of re-establishing SA, based on the features of each mode (i.e., re-familiarizing oneself with image chips).

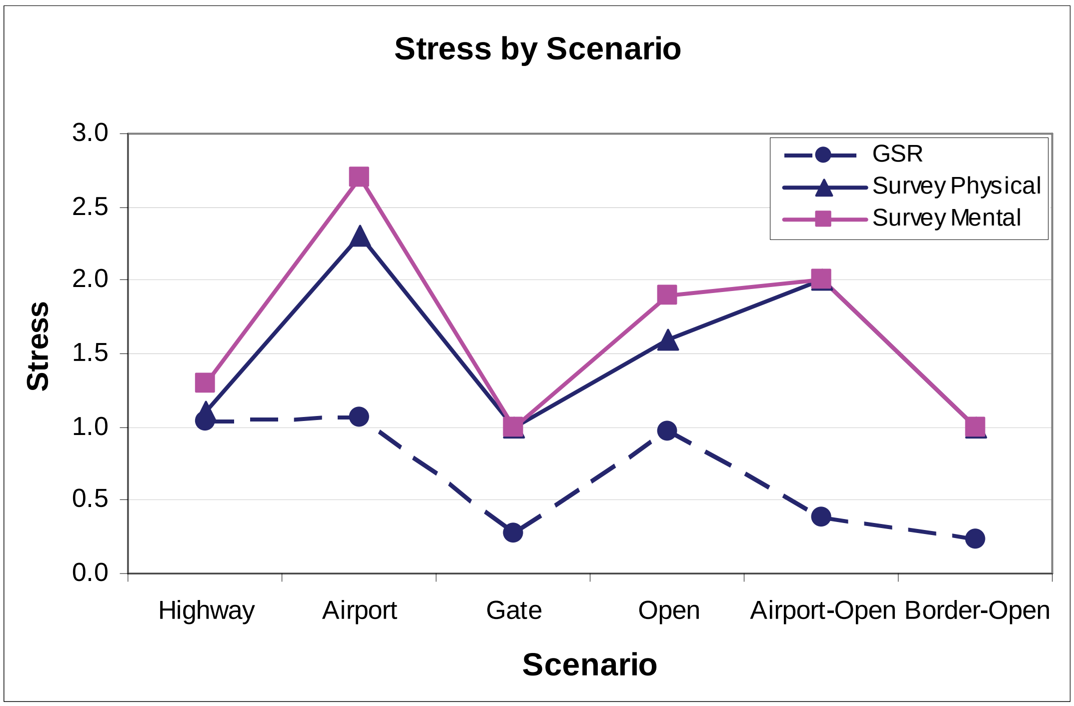

Figure 4. AiTR experiment GSR and survey stress by scenario.

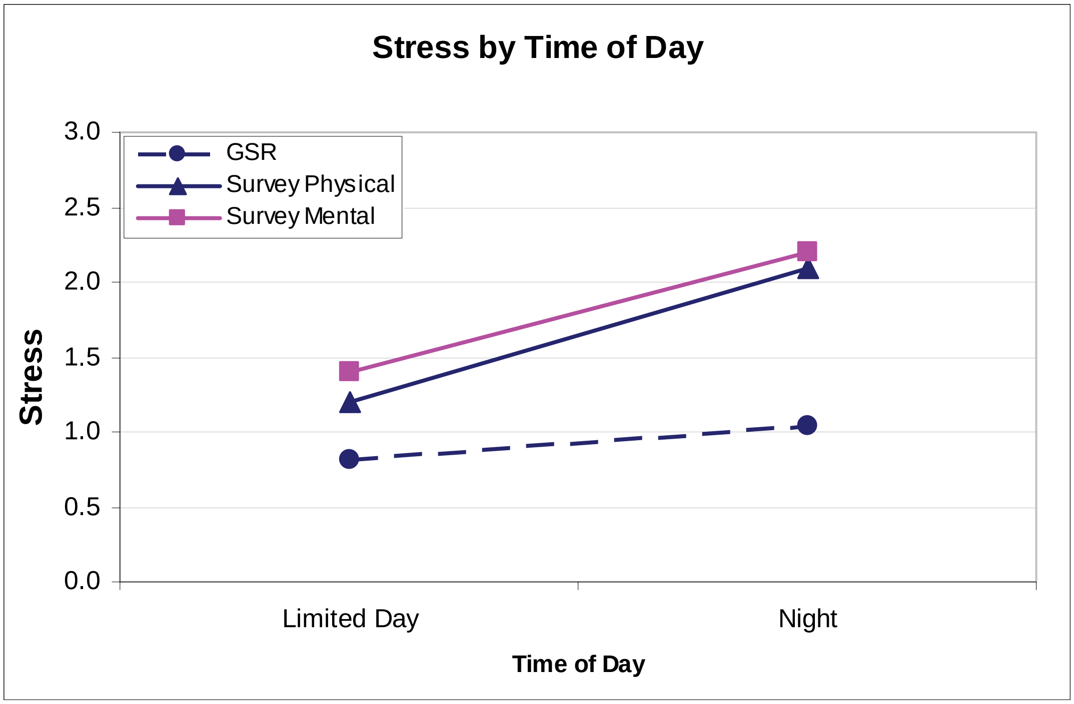

Figure 5. AiTR experiment GSR and survey stress by time of day.

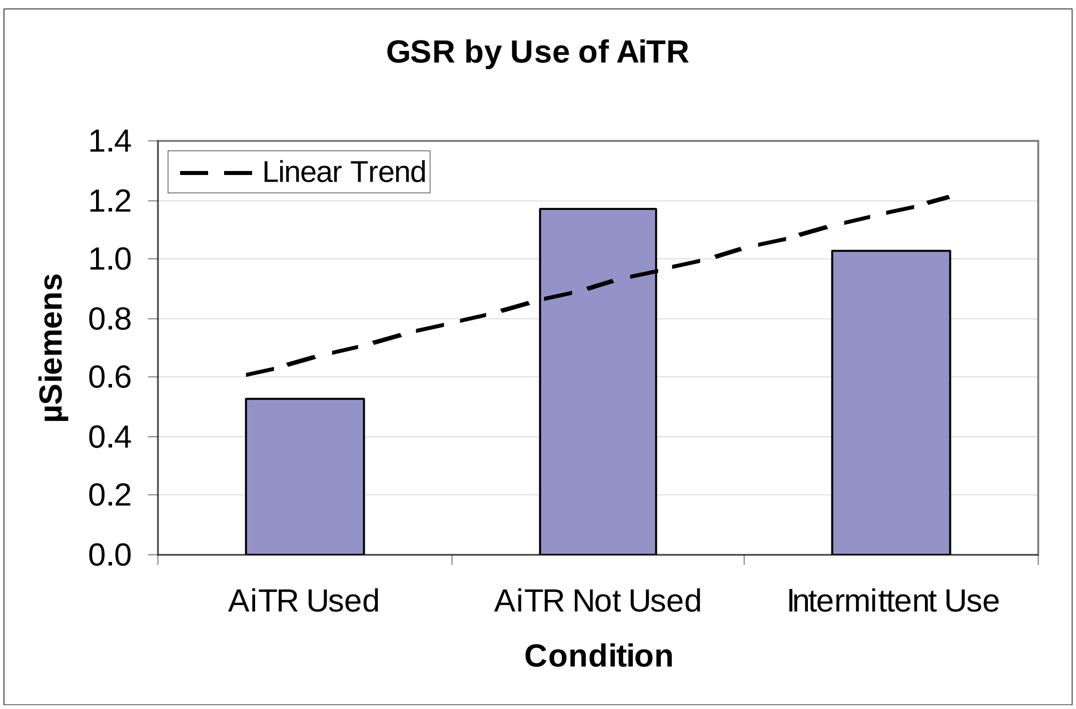

Figure 6. AiTR experiment GSR stress by use of AiTR.

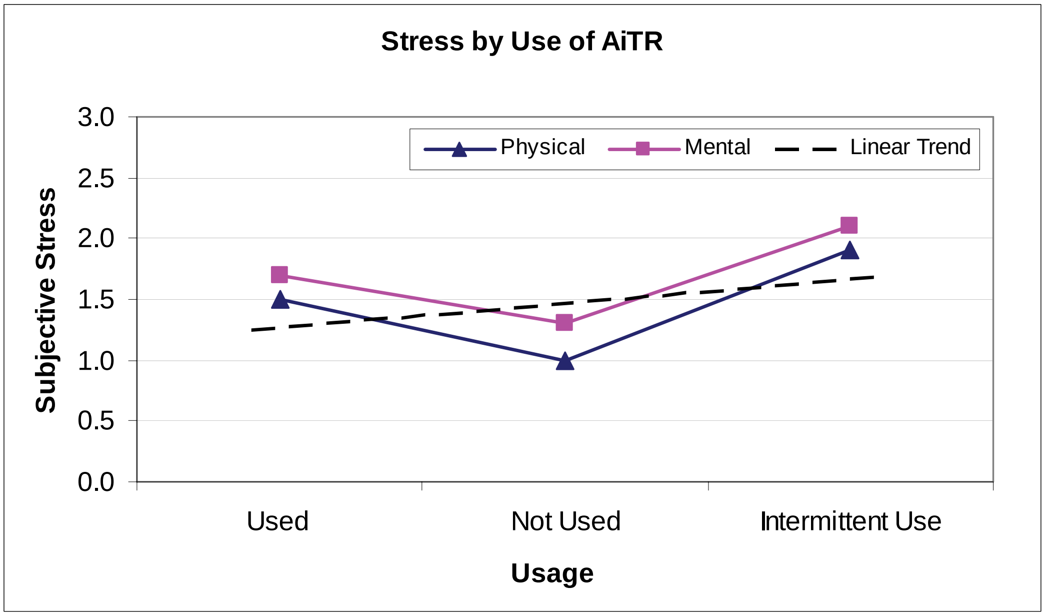

Figure 7. AiTR experiment survey stress by use of AiTR.

3.3 Crew-Aiding Behavior and Lethality Experiment

3.3.1 Introduction

As the U.S. Army network-centric digital battlefields continue to expand, so do the workload demands placed on Soldiers who use the increasing amount of information to conduct their missions. In an effort to reduce workload and stress for these Soldiers, decision aids, called crew-aiding behaviors (CABs), have been developed which provide a level of automation designed to assist Soldiers in the performance of their tasks. A field-based experiment was conducted to assess the effects of these decision aids on Soldier performance in a simulated battlefield environment. We evaluated the effects of the CABs by measuring and comparing levels of task time, workload, stress, and SA between two experimental conditions. The experimental task was target prioritization, weapon system and munition matching, and target engagement with and without the use of the decision aids.

This experiment, known as the Lethality Experiment, was one of several experiments conducted under the name of the U.S. Army Research Development and Engineering Command (RDECOM)-Unit of Action Maneuver Battle Lab (UAMBL) Experiment Fiscal Year 2006 (RUX06). These experiments were conducted jointly among RDECOM, specifically, ARL's HRED; Tank Automotive Research Development and Engineering Center; Aviation and Missile Research Development and Engineering Center (AMRDEC); and UAMBL in support of the Crew-integration and Automation Test Bed Advanced Technology Demonstration program (CAT-ATD). Experimentation was conducted at Fort Knox, Kentucky, in July 2006.

The objective of this research was to determine the impact of CABs on Soldier workload, stress, SA, and performance. Specifically, this experiment examined the effectiveness of CABs designed to prioritize targets (based on threat level and proximity) and to provide weapons platform and munition recommendations to service each target.

3.3.2 Method

This experiment took place entirely in simulation; however, the crew station was identical to that used in the actual field vehicle. The SIL interface (figure 8) consisted of three vertically oriented liquid crystal displays situated in an arc in front of a seated participant. Each display was divided in two, horizontally, with information on each of the six "screens" being provided from various computer systems, which were transparent to the SIL operation and the participant. Figure 9 shows the basic layout of the three displays (six screens) used during this experiment, with the target prioritization list on the center display. Participants could select targets and weapons by touching on-screen buttons or by scrolling through the list using a thumb button on the driver's yoke. The yoke was also used to slew the weapon system and to engage each target. Detailed information regarding each screen and button functions is available in appendix E.

Figure 8. CAT SIL crew station simulator.

Twelve active duty male Soldiers volunteered for this experiment. One Soldier was a Captain (O3), seven Soldiers were Sergeants First Class (E7), and four Soldiers were Staff Sergeants (E6). Military occupational specialties were primarily M1 Armor Crewmen (19K). Nine participants were 19K, one 19D (Cavalry Scout), one 14E (Patriot Fire Control Enhanced Operator), and one 25B (Information Systems Operator-Analyst).

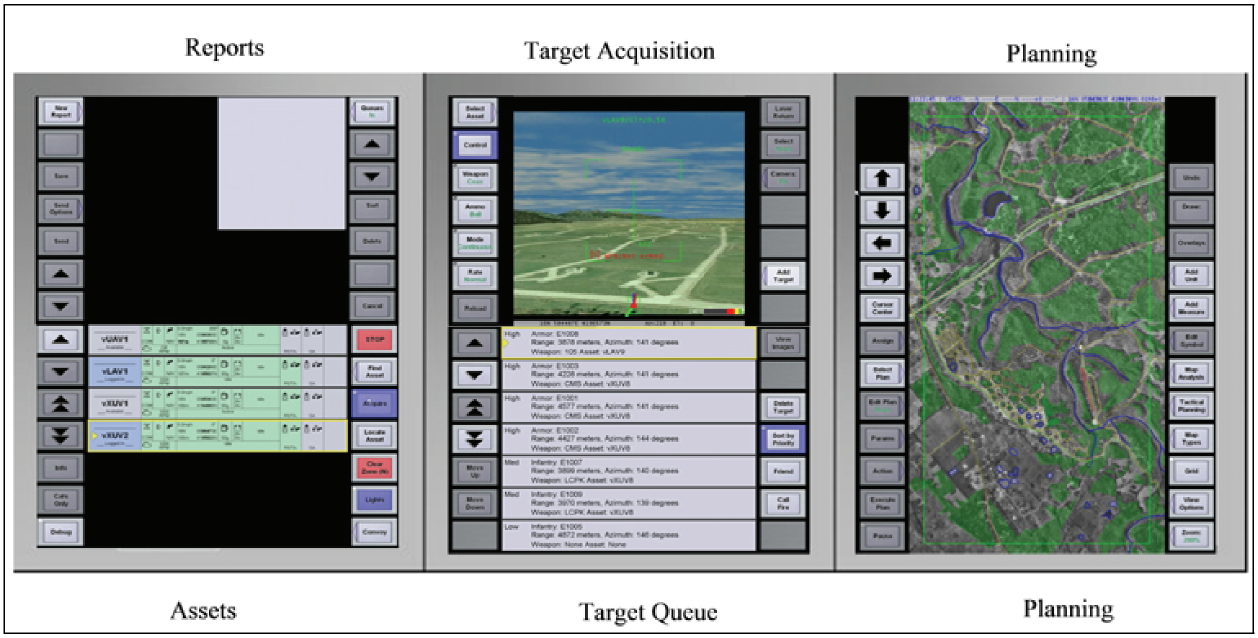

Figure 9. CAT SIL display layout.

Participants were given a 1-hour block of instruction and practice for the task of prioritizing and servicing a list of targets, in both CAB and NoCAB conditions. The instruction consisted of familiarization with the displays and controls and a detailed explanation of the tasks, conditions, and standards for the experiment. Depending on which condition was presented first, training for that condition was presented before experimentation. For example, if a participant was testing in the CAB condition first, the CAB training was conducted before testing in the CAB condition. Following testing and a short break, the NoCAB training was conducted before the NoCAB test.

Subjective stress measurements were collected with one-item rating scales that measure physical stress and mental stress. These measures are based on each participant's subjective assessment of his own perceived levels of stress within a given experimental condition or session. Objective stress measurements were collected via the SenseWear Pro2 armband.

3.3.3 Results

Physical stress was only slightly non-significant. Even though no significance was observed, the general trend of increasing stress (both mental and physical) may be seen between CAB and NoCAB (figure 10). That is, mental and physical stress are higher in the NoCAB condition than in the CAB or Baseline conditions. Although not statistically significant, it is believed this difference would become so with a larger sample size. As can be seen in figure 11, GSR results generally parallel the results of the subjective ratings, with stress in the Baseline and CAB conditions being equivalent and stress in the NoCAB condition being higher.

A correlation analysis conducted for this study was used to determine if a correlation existed between the two different types of stress data and not to support a specific hypothesis regarding the two methods of data collection used to obtain the data.

No significant correlation existed between the subjective stress data collected by survey and the objective GSR stress data collected by the armband. However, data from both methods show a distinct trend of increasing stress in the NoCAB condition (versus Baseline and CAB conditions).

In summary, the analyses of variance (ANOVAs) show that the higher levels of stress observed in the NoCAB condition, in the survey and GSR data, were not significant. Further, there was no correlation between stress measurement methods.

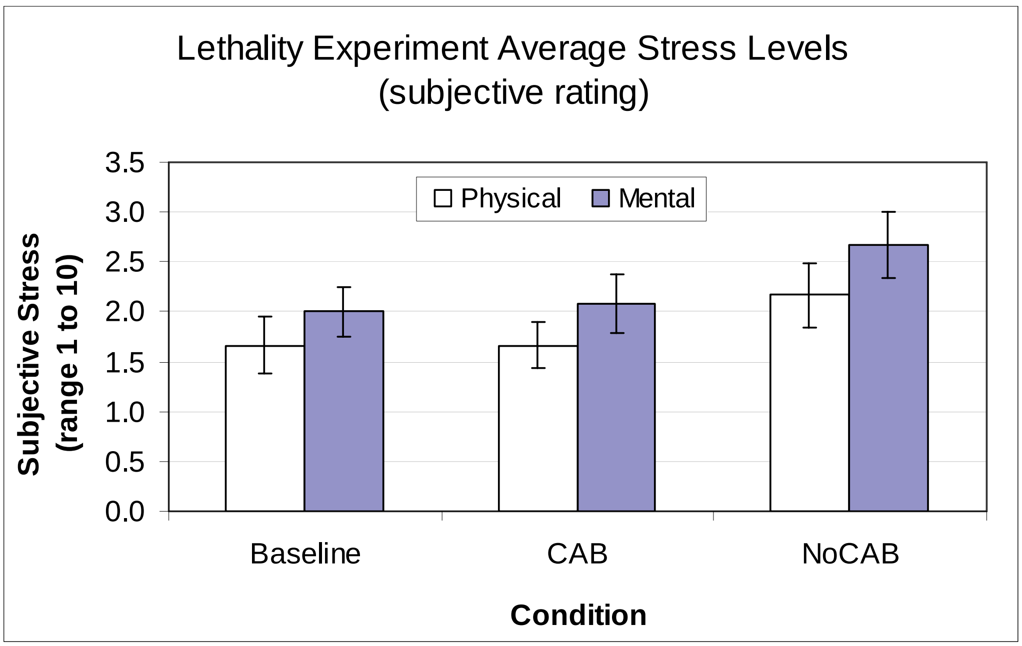

Figure 10. Comparison of physical and mental stress across conditions.

First, the non-significant ANOVA results may be entirely attributable to the small sample size. The graphs in figures 10 and 11 clearly show the trend of increasing stress in the NoCAB condition, compared with the Baseline and CAB conditions. Further, the graphs show that the stress levels in the CAB condition are more closely aligned with the Baseline condition. It is believed that a larger sample size would demonstrate that this trend toward greater stress in the NoCAB condition would be statistically significant.

Second, the fact that no correlation exists between the stress data captured by the two different methods may only illustrate that again, the small sample size was simply too small to achieve statistically significant results. As previously stated, both sets of data clearly show the trend of increased levels of stress in the NoCAB condition when compared with the Baseline and CAB conditions.

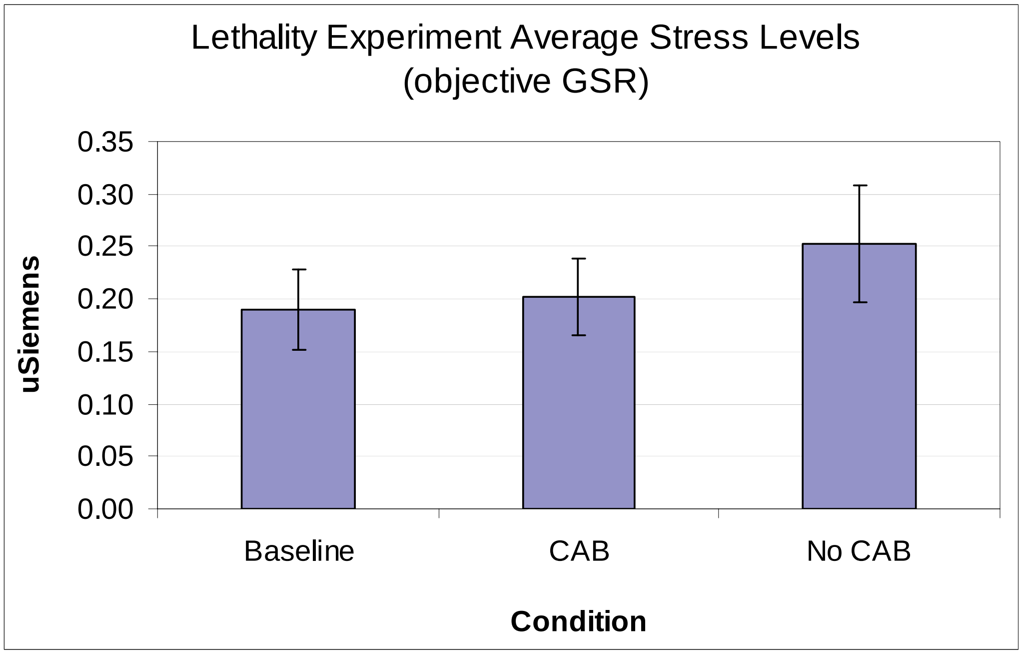

Figure 11. Comparison of GSR stress data across conditions.

4. Overall Assessment/Comparison Between Methods

This research suggests that GSR is a promising measure of stress. Although there was no subjective measure of stress with which to compare GSR in the HTSS experiment, the GSR results seemed to make sense. The confined space and unpredictable nature of the targets in the MOUT environment was more stressful to the participants (with both the HTSS and NVGs) than the less eventful and more familiar scenario experienced in the movement environment. Further, stress using an unfamiliar technology to identify targets (HTSS) was higher than stress identifying targets with the traditional "head-out-of-the-hatch" view.

In the AiTR experiment, there was reasonable correspondence between subjective stress measures and GSR. Survey and GSR results were somewhat inconsistent in that the airport scenario was highest for the survey measure, but the airport, highway, and open scenarios were equally stressful as measured by GSR. The survey and GSR measures were all higher for night versus day scenarios. Also, the survey and GSR measures were consistent in that both were higher for intermittent use of AiTR versus constant use of AiTR.

In the targeting experiment, the survey and GSR measures of stress were consistent in that both measures showed that the Baseline and CAB conditions were about equally stressful, while the NoCAB condition, as might be expected, was the most stressful.

4.1 Caveats in the Current Report/Study

Of course, all the research efforts just described have drawbacks in that relatively few participants were used. The AiTR study had further problems since there was no control or ability to counterbalance conditions; thus, no inferential statistics were possible. More controlled research with more participants is necessary for a more robust comparison among these methods.

5. Recommendations for Further Research

To measure Soldier stress levels during training exercises or during scientific experimentation, it is desirable to have a fast, reliable, objective, and non-intrusive method for collecting stress data. Surveys are subjective and rely entirely on biased self-reporting. Salivary amylase is objective and reliable, but it is neither fast nor non-invasive. Using a bio-instrumentation device to collect GSR data appears to offer the better solution, since it is non-invasive, reliable, expeditious, and collects data continuously throughout a training mission or experimental session. This makes it ideal for researchers in the field.

It is suggested that to determine which is the better solution in terms of time to collect data, accuracy, invasiveness, and preference (both experimenter and participant), a study be conducted with all three methods of data collection: subjective surveys, objective GSR, and objective salivary amylase. It is hypothesized that the objective methods will exhibit high positive correlations with each other, thereby demonstrating that GSR is an acceptable method (at least when compared with salivary amylase) for collecting stress data in the field. Further, it is suggested the subjective method data will not correlate with data from either objective method, although it is expected to exhibit similar trends.

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Appendix A. Stress Survey

Participant ID:_____ Date:________ Time:________ Experiment:_______ Condition:_______

Subjective Stress Rating Scale

a. The scale below represents a range of how PHYSICALLY stressful the mission might be. Check the block indicating how PHYSICALLY stressful the mission you just participated in was.

Task	Not at All Stressful 1	2	3	4	5	6	7	8	9	Most Possible Stress 10
a. Overall stress										

a. The scale below represents a range of how MENTALLY stressful the mission might be. Check the block indicating how MENTALLY stressful the mission that you just participated in was.

Task	Not at All Stressful 1	2	3	4	5	6	7	8	9	Most Possible Stress 10
a. Overall stress										

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Appendix B. Armband Specifics

Manufacturer's Data Sheet for the SenseWear Pro2 Armband

SenseWear® PRO 2
Armband

Product Features

The SenseWear™ Pro 2 Armband is a sleek, wireless, wearable body monitor that enables continuous physiological and lifestyle data collection outside the lab environment. Worn on the back of the upper right arm, it utilizes a unique combination of sensors and technologies that:

- Gather raw physiological data such as movement, heat flow, skin temperature, ambient temperature, and galvanic skin response.
- Can be worn up to 14 days continuously without changing the battery.
- Stores up to 14 days of continuous physiological and lifestyle data.
- Allows research subjects to timestamp specific events.
- Compatible with our InnerView™ Research Software.**
- Offers audio and tactile feedback for reminders and alerts.**
- Enables 2-way communication, making the Armband a hub for collecting data from other third-party products such as a weight scale or blood pressure cuff***
- Eliminates the need for researchers and clinicians to administer and apply cumbersome sensors to their research subjects

BODYMEDIA

** Requires separate purchase of InnerView™ Research Software   *** Requires separate purchase of SenseWear™ Pro Transceiver.

Product Specifications

- Sensors
  2-axis accelerometer
  heat flow
  skin temperature
  ambient temperature
  galvanic skin response
- RF Frequency: 916.5MHz
- Transmitter output power: < 1mW
- Processor:
  16-MHz Motorola DragonBall™ Processor
- Battery type: AAA
- Size:
  Monitor (without wings): (l) 85.3mm x (w) 53.4mm x (h) 19.5mm [(l) 3.4 in x (w) 2.1 in x (h) 0.8 in]
- Weight:
  Monitor (with adjustable strap): 3.0 oz (85g)
- Materials:
  Monitor: ABS, urethane, FDA approved co-polyester, hypoallergenic grade stainless steel
  Adjustable Strap: Nylon, polyester, polyisoprene (no latex) and can fit 8.5 in - 17 in or 16 in - 24.5 in arm circumference
- Operating temperature/humidity:
  0°C to +45°C (32°F to 113°F)/100% RH non-condensing
- Storage temperature/humidity:
  0°C to +45°C (32°F to 113°F)/100% RH non-condensing
- Water resistance:
  Monitor: splash-resistant
- Certifications
  FCC 47CFR 15C TCB - 47 CFR Part 15 Subpart C Intentional
  FCC 47CFR 15B dA - 47 CFR Part 15 Subpart B Unintentional Radiators Class A Verification
  UL 60601-1 UL Standard for Saftey Medical Electrical Equipment, Part 1: General Requirements for Safty First Edition
  CENELEC EN 60601-1-2- 2001 - Medical Electical Equipment Part 1-2: General Requirements for Safety - Collateral Standard: Electromagnetic Compatibility - Requirements and Tests IEC 60601-1-2:2001
  CENELEC EN 60601-1-1 - Medical Electric Equipment - Part 1: General Requirements for Safety - Collateral Standard: Safety Requirements for Medical Electrical Systems.
  CAN/CSA-C22.2 No.606.1-M90

System Requirements

- PC with Pentium II processor or higher
- Windows 98/2000/ME/XP
- Win 2000 users need service pack 3 or higher
- 128 MB RAM or higher
- One available USB port
- InnerView™ Research Software

Comes with:

- 2 AAA batteries
- 2 Adjustable velcro arm straps
- 1 USB cable

To order:

Contact our sales department for more information.

sales@bodymedia.com
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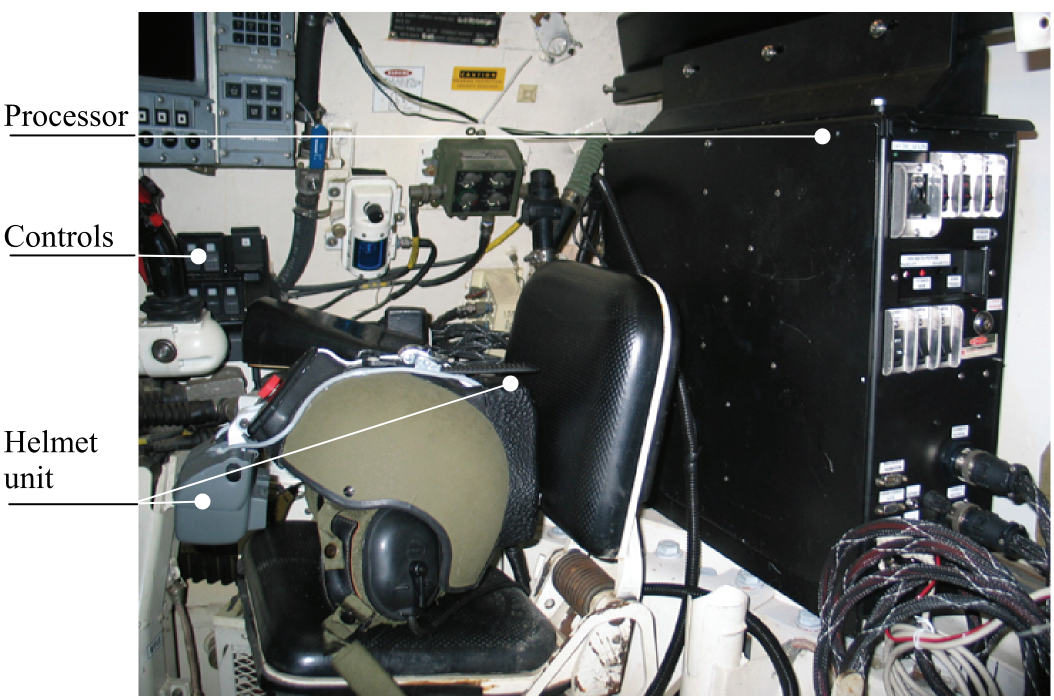
Appendix C. HTSS Components

HTSS gimbaled sensor platform mounted to test vehicle



HTSS components (inside an M1A2 tank)

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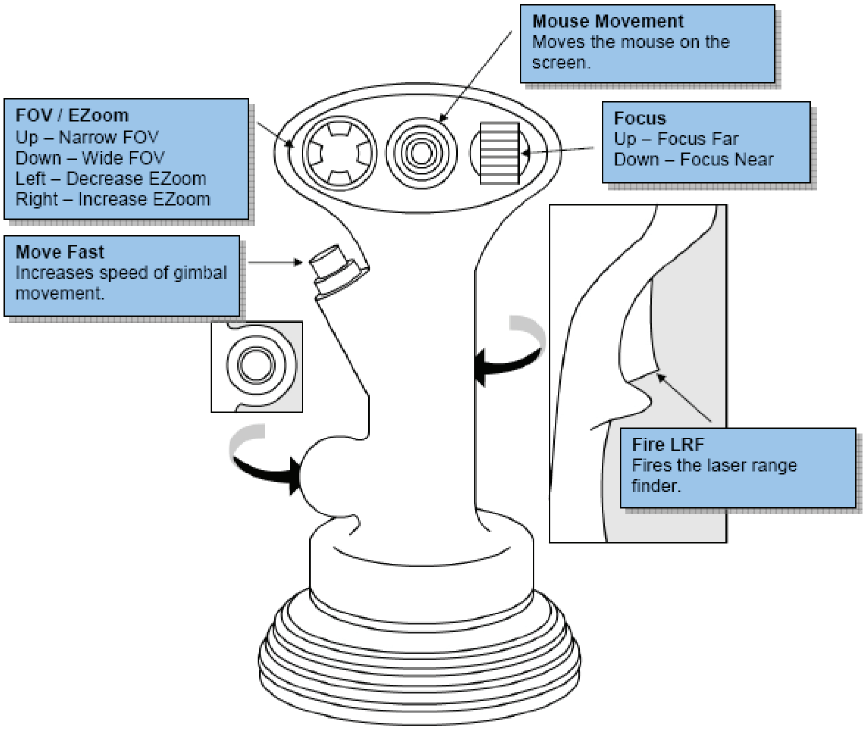
Appendix D. AiTR User Interface

AiTR crew station



joy stick controller

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Appendix E. CAT SIL Screen and Button Functions

(from AMRDEC training slides)

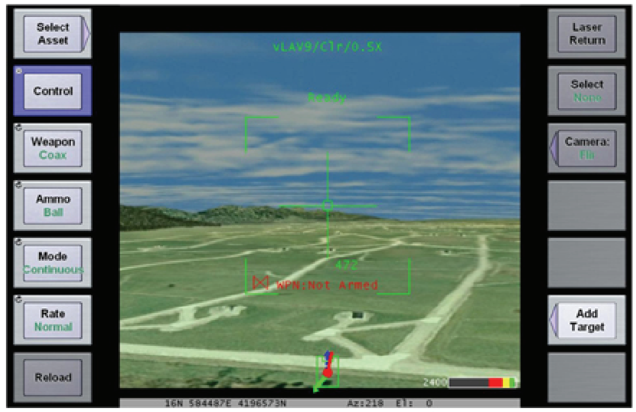
Target Acquisition Display – Yoke Controls

Magnification

- Increase / decrease the TA sensor magnification from 0.5X to 24X.

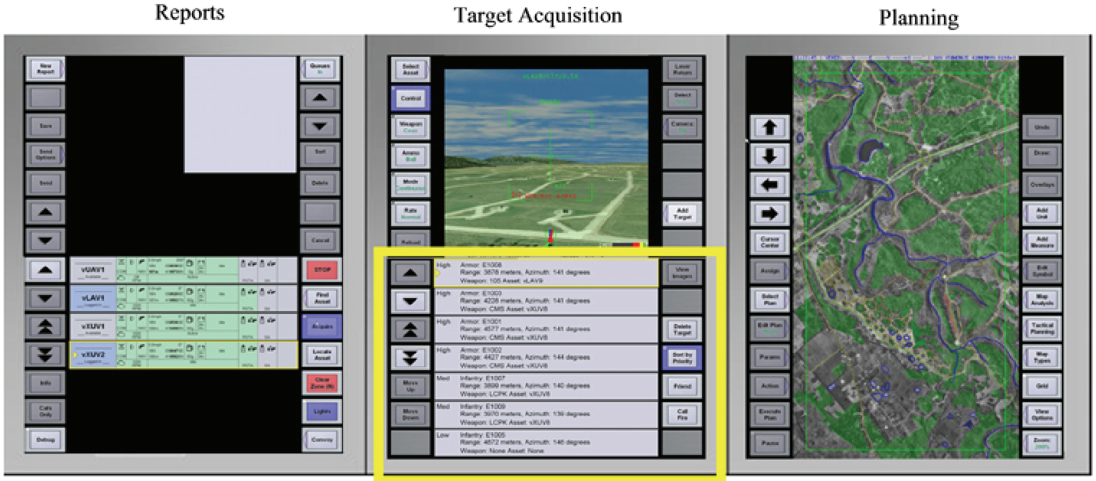
Slew

- Slew TA sensor left / right
- Tilt TA sensor up / down



Fight Suite – Target Queue

Reports
Target Acquisition
Planning



Assets
Target Queue
Planning

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